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LLNL-CONF-436075

Inferring SRS character from time-dependent measurements of backscatter in NIF hohlraums

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June 16, 2010

40th Anomalous Absorption Conference
Snowmass Village, CO, United States
June 13, 2010 through June 18, 2010

Disclaimer

National Ignition Campaign

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Presentation to the
40th Annual Anomalous Absorption Conference
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14 June 2010

Lawrence Livermore National Laboratory

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Collaborators

This work is done in collaboration with:

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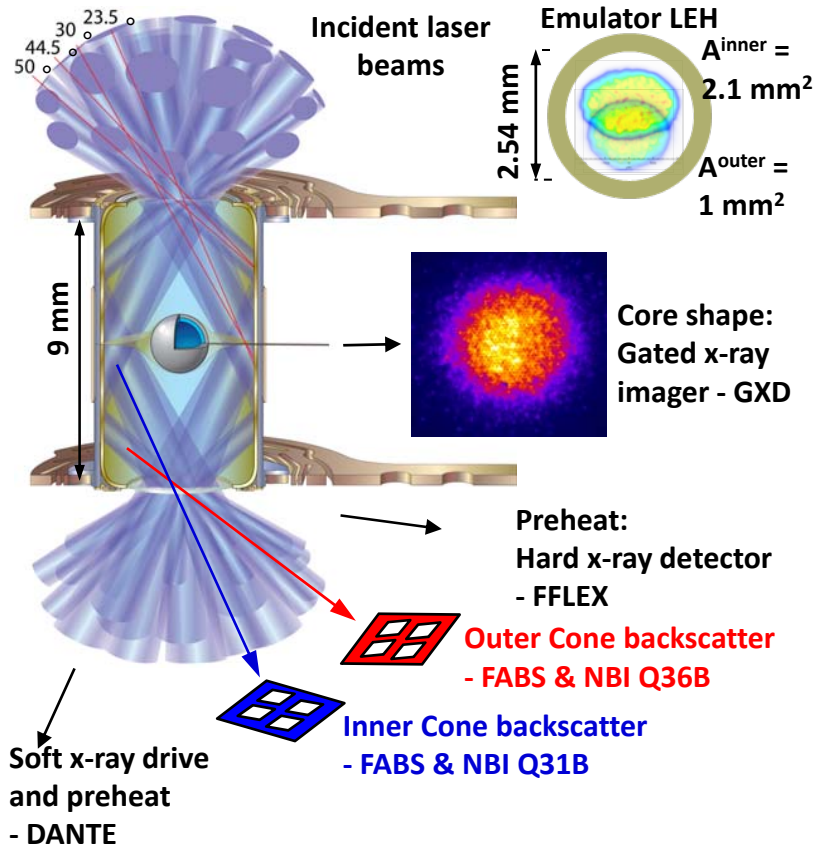
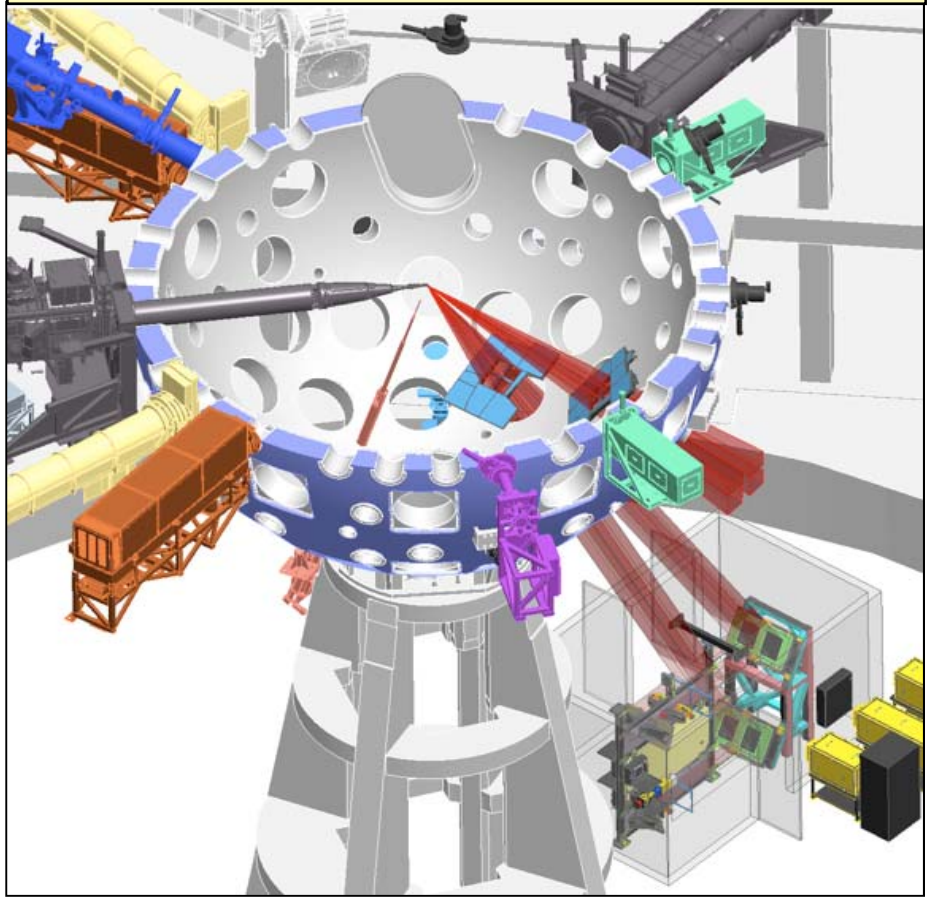
The backscatter measurement is important for quantifying the energetics aspects of ignition hohlraums

Hohlraum heated by 192 beams emulating ignition conditions



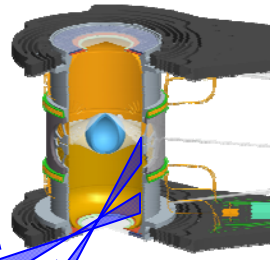
Backscatter instruments (FABS / NBI) are installed on two beam quads

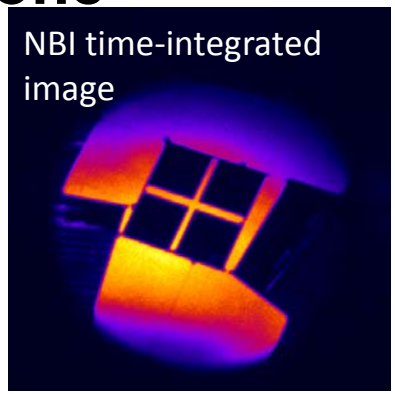


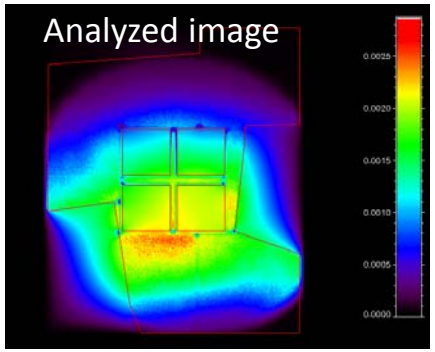
We have installed backscatter diagnostics on an inner and outer beam cone

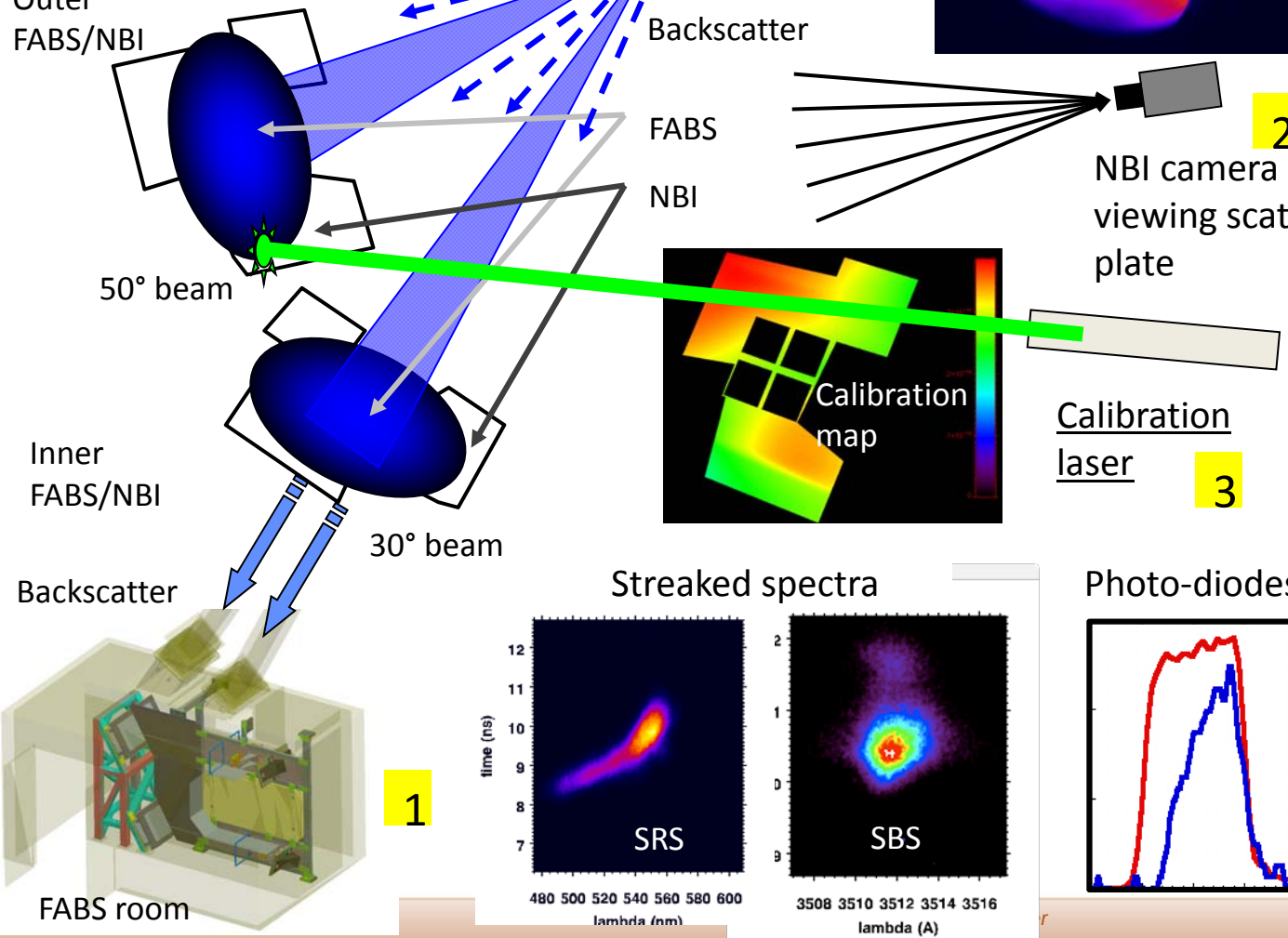
Accuracy requirement:

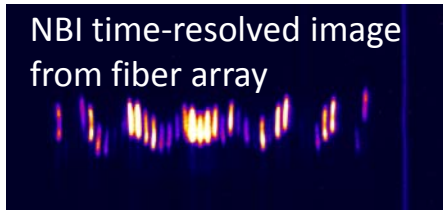
15% error at 15% backscatter

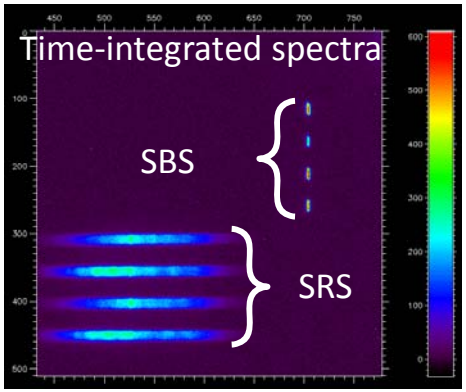






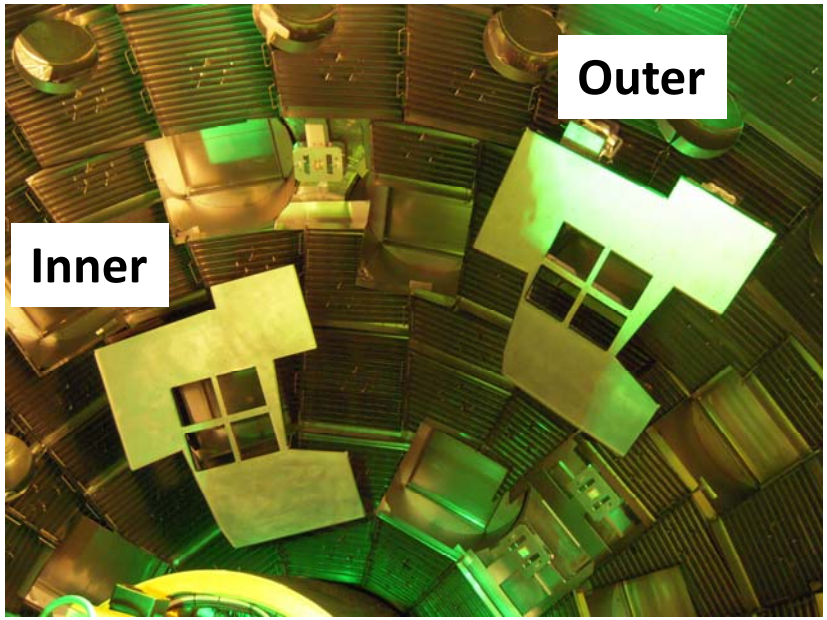


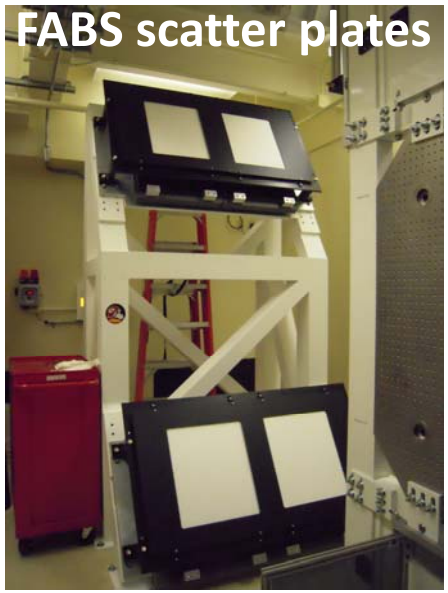


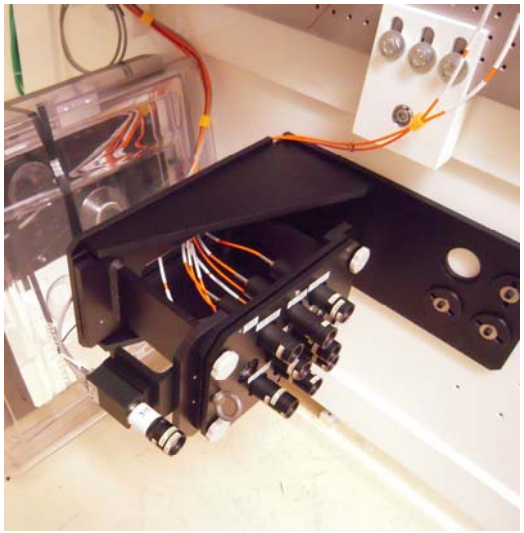


- 200 ps time resolution
- 5 nm SRS; 0.3 Å SBS

Backscattered instruments installed on NIF

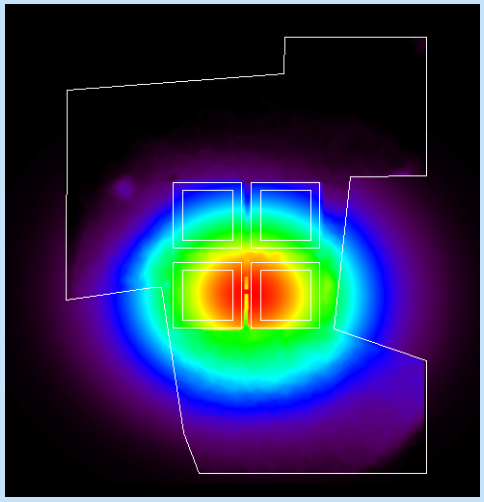




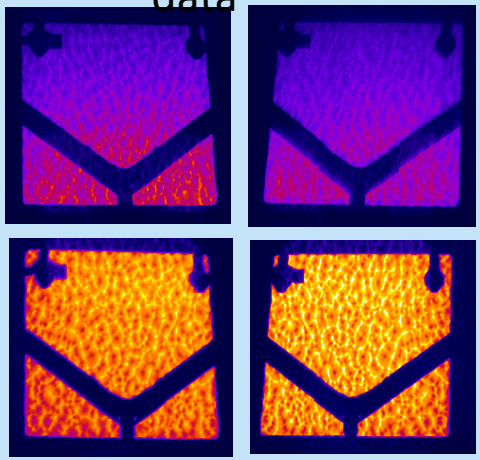


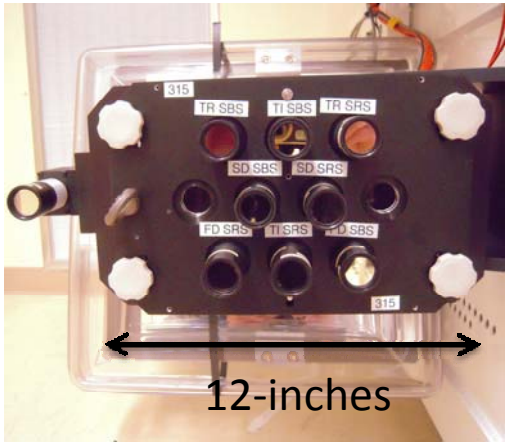
Fiber pickoffs

NBI data



FABS data



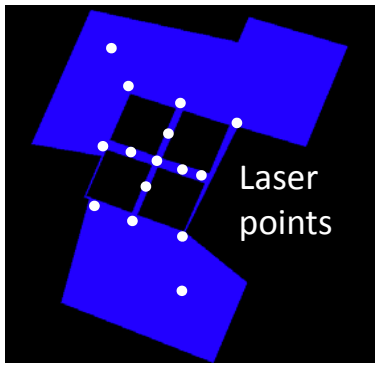


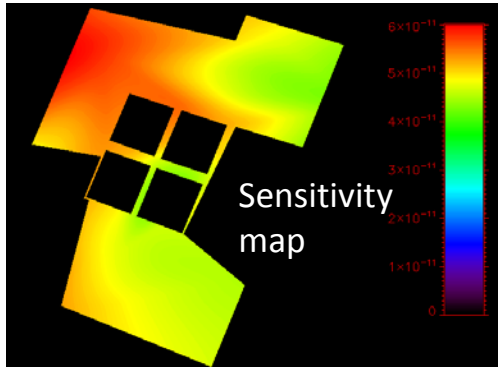
Filter holder

Backscatter calibration combines several techniques to achieve ≥ 15% relative accuracy

1) Pulsed laser calibration - 2 wavelengths, S and P polarization. Calibrates FABS diodes for *power* and NBI sensitivity

Pulsed laser

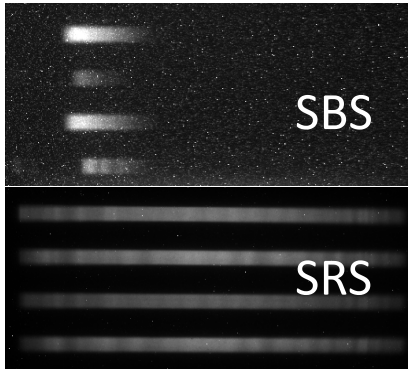




14% error

2) White light Xe lamp. Calibrates calibration spectrometer for FABS energy

Xe lamp



20% error

17% error

Wavelength

Optical filters

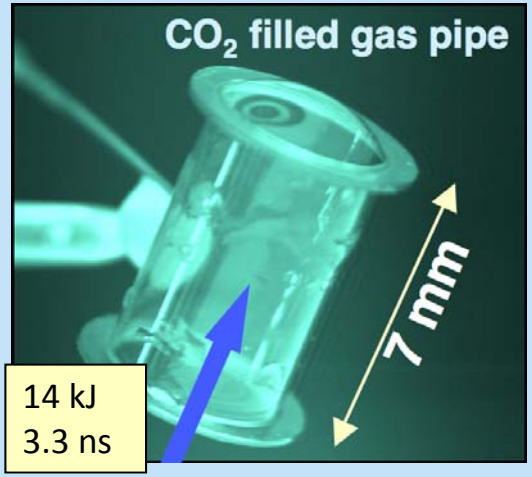
Pencil calibration lamp

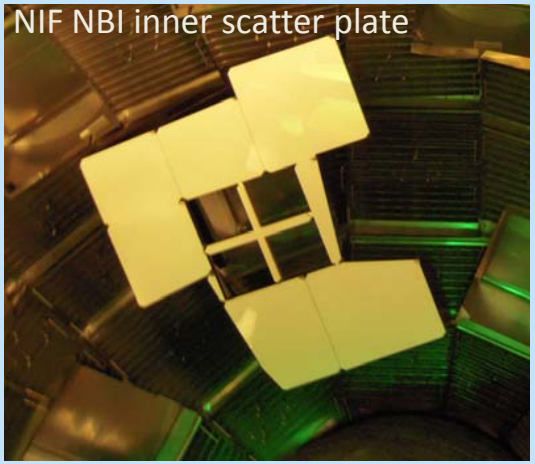
3) Spectrometers are calibrated using standard Hg or Ne calibration lamps. Instruments and filters are calibrated off-line

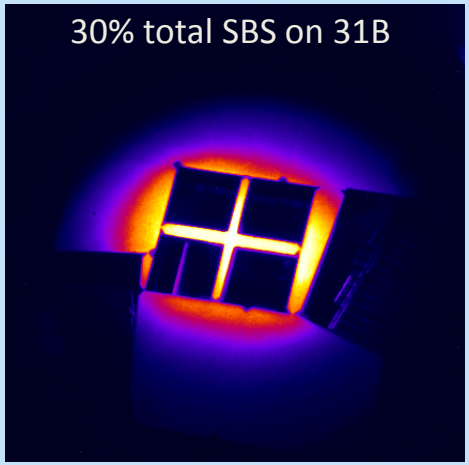
FABS / NBI calibration is based on several independent measurements. Accuracy estimates are determined by the relative agreement between these

Large scale length 7 mm-long plasmas have been produced with 1 quad of beams to activate scattering diagnostics

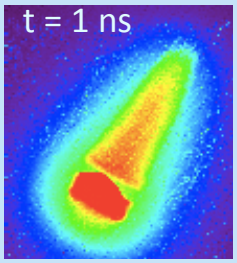
Near Backscatter Imagers measure SBS and SRS around inner (Quad 31B) and Outer (Quad 36B) beams

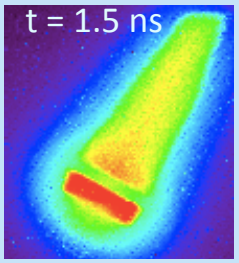


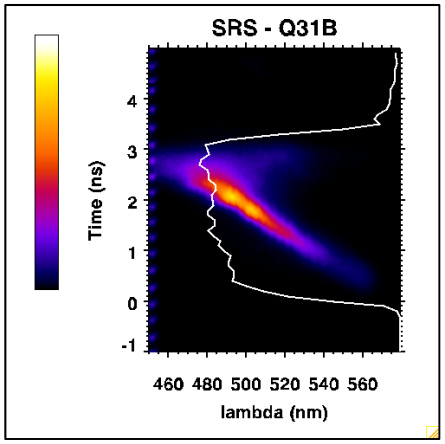


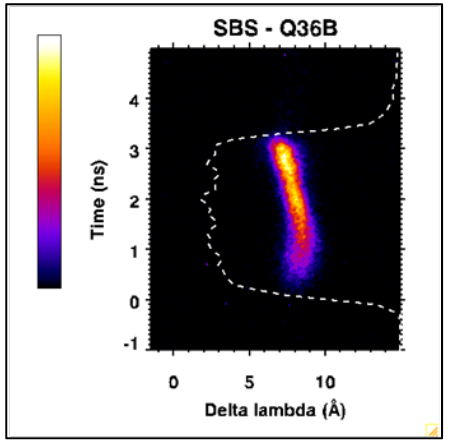


Gated x-ray data indicate burnthrough at t = 1.5 ns









We have performed experiments to measure the backscatter from cryogenic gas-filled hohlraums

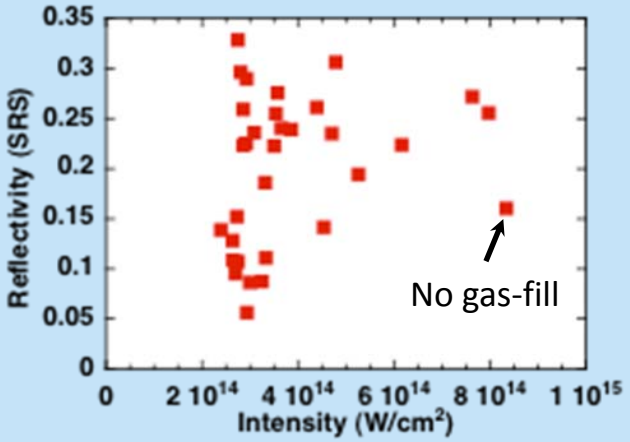
Cryogenic hohlraum target with shields; He-H2 gas-fill at 20.6 K

Some important results from hohlraum experiments:

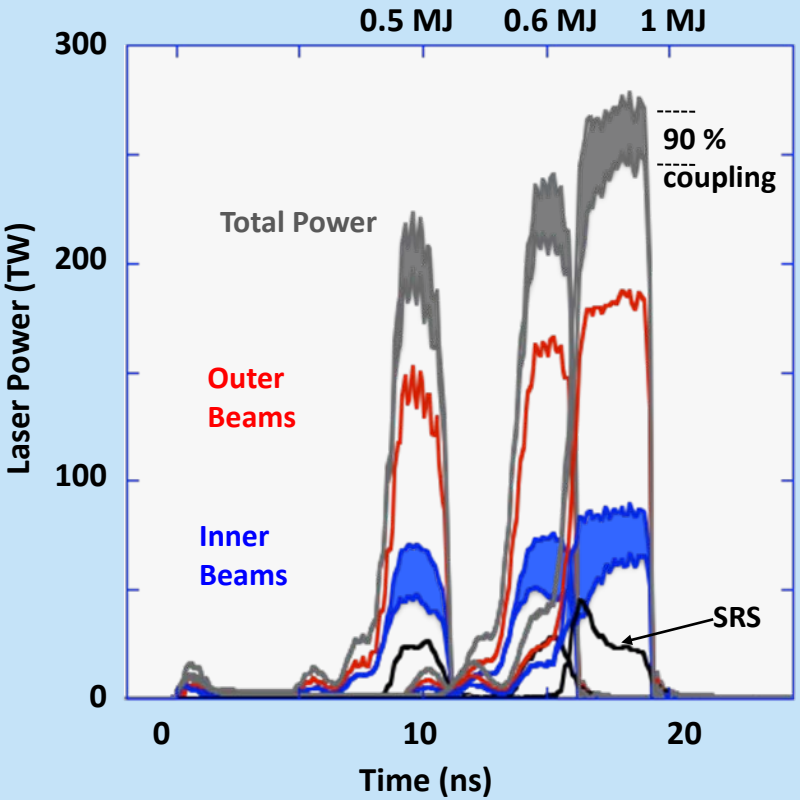
- LEH liners give high backscatter
- Pure He is better than He/H2 fill
- Pure Au is as good as Au/B
- Checkerboard PS is better
- $\Delta\lambda$ tuning capability is important

Inner beam backscatter is ≤ 10%

Inner SRS and SBS from hohlraums

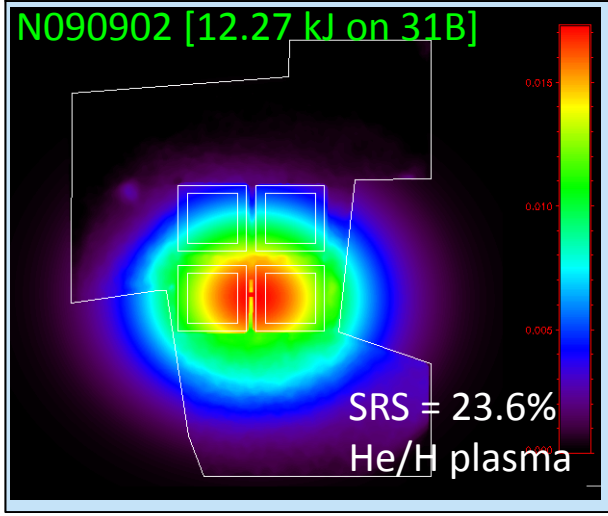


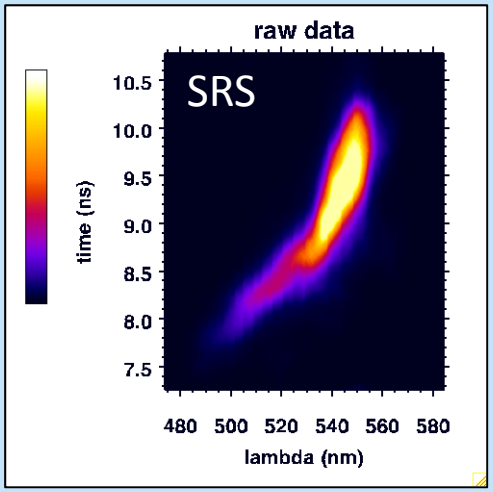
Total SRS is ≤ 10% up to 1 MJ

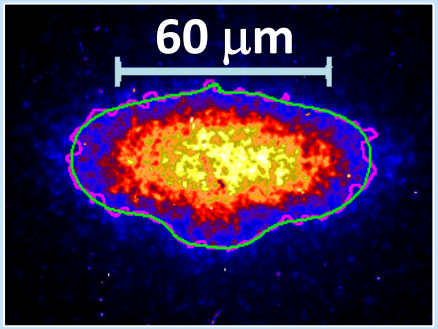


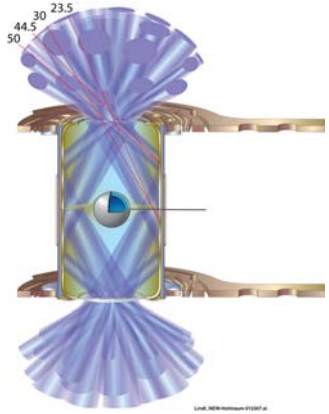
Wavelength tuning counteracts the SRS inner-beam losses in cryogenic gas-filled hohlraums

Inner and outer cone wavelength separation: Δλ = 1.5 Å



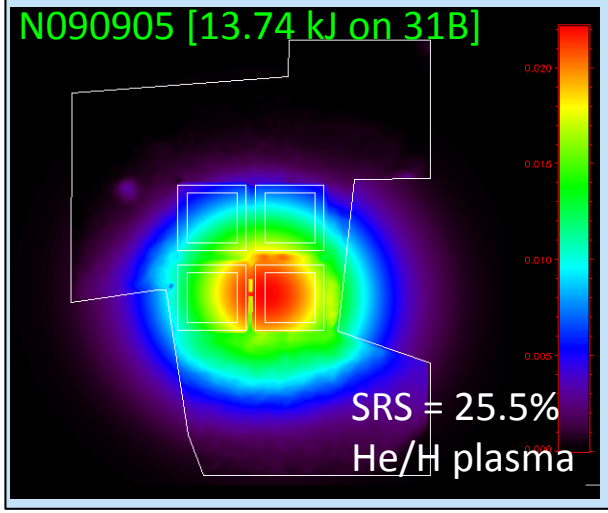


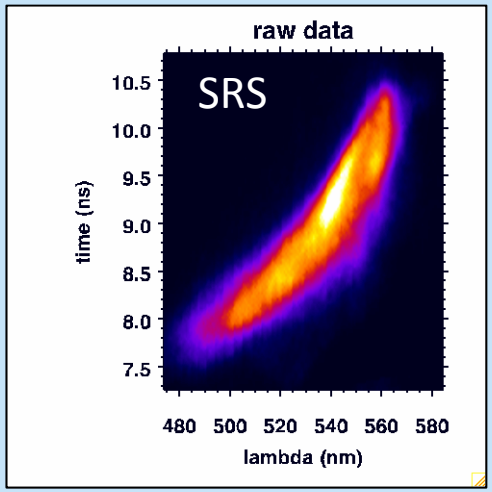


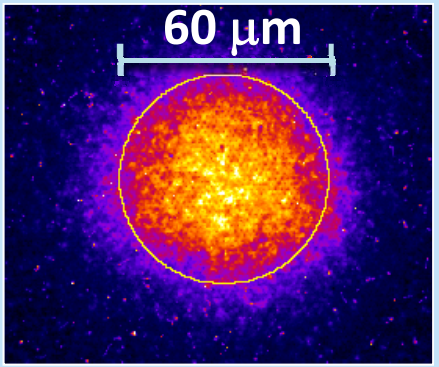


Hohlraum orientation

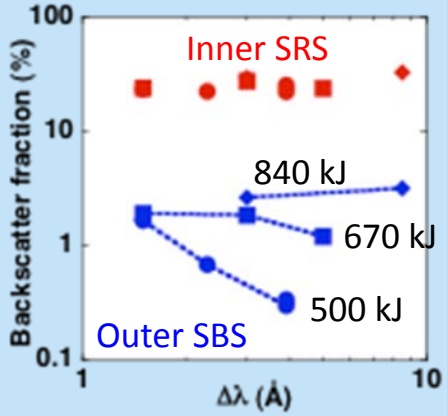
Inner and outer cone wavelength separation: Δλ = 3.9 Å





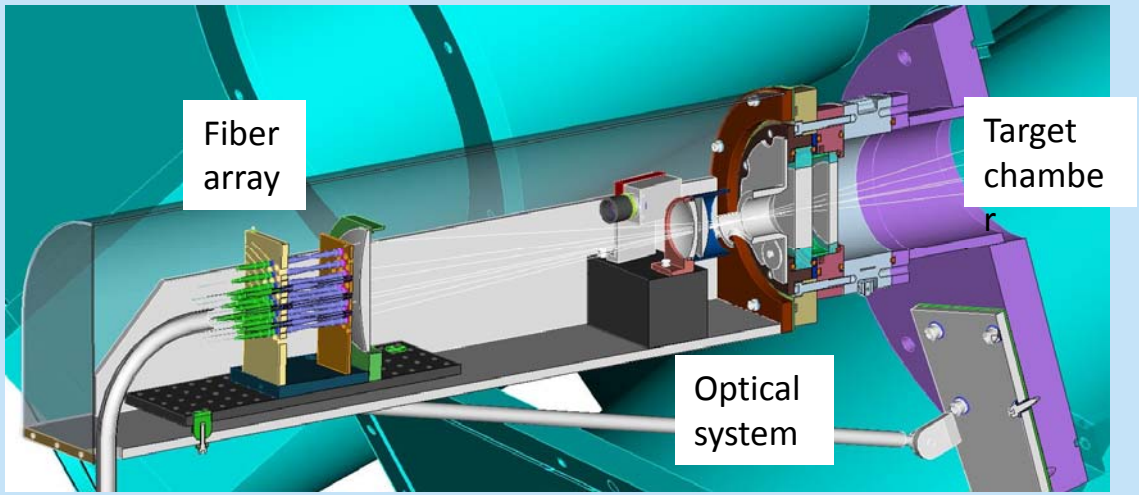


Outer SBS

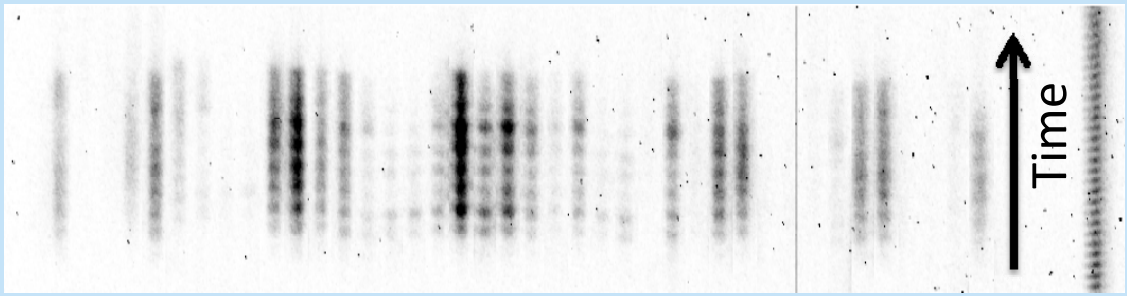


Time-resolved NBI utilizes 40 fibers and a streak camera

Sketch of NBI-time-resolved system

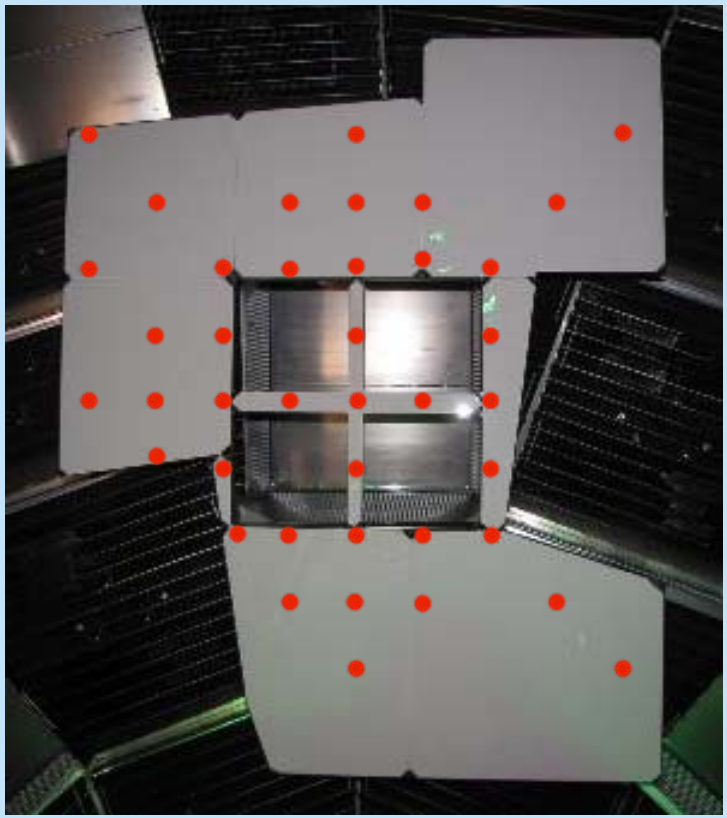


Fiber streaks

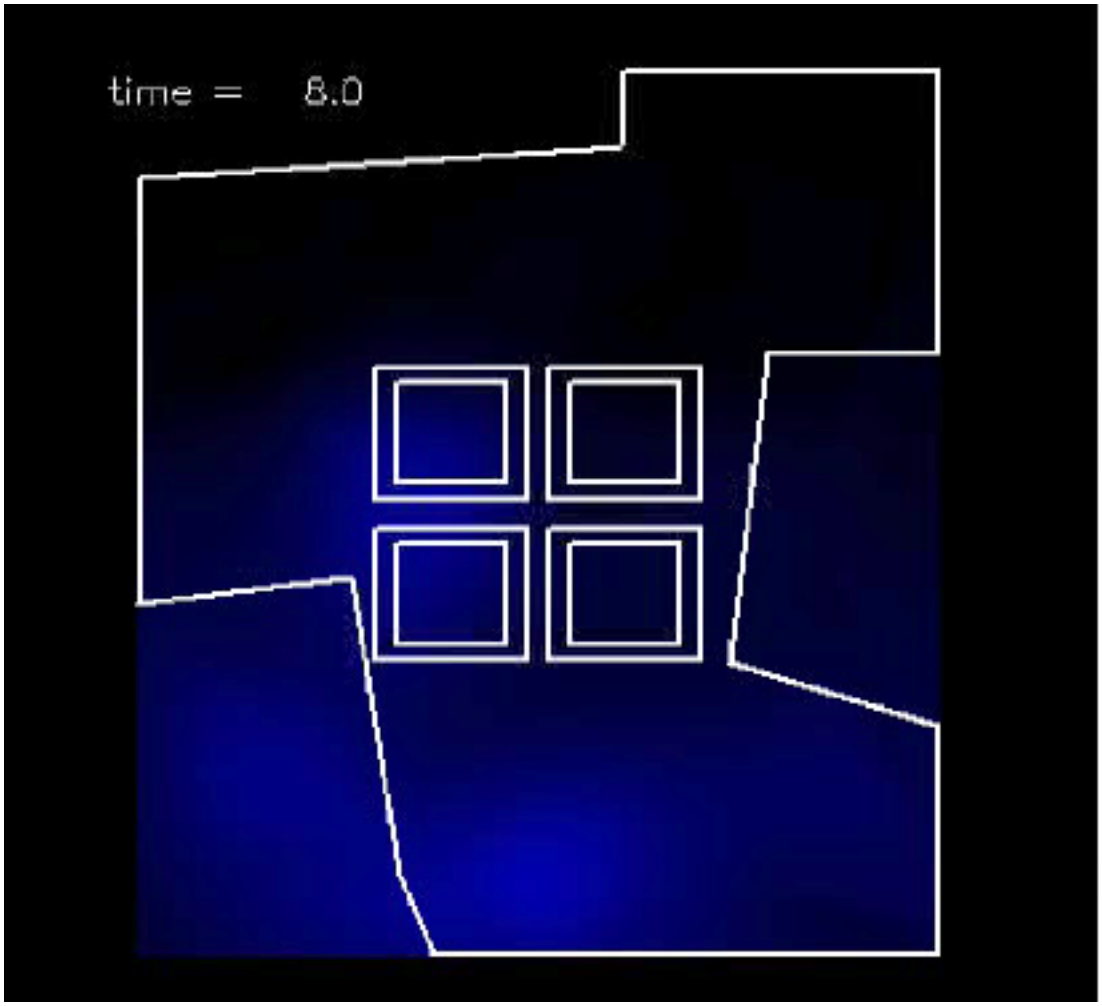


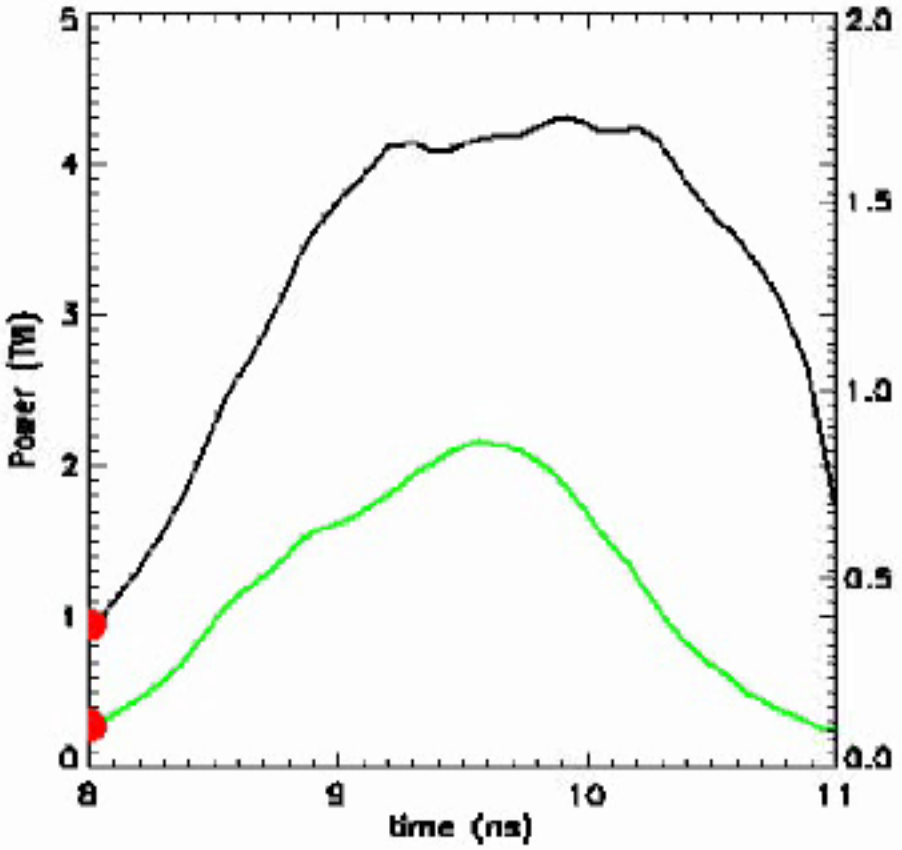
Data corrected for propagation time

Scatter plate with fiber views



NBI movie for a hohlraum with an LEH liner

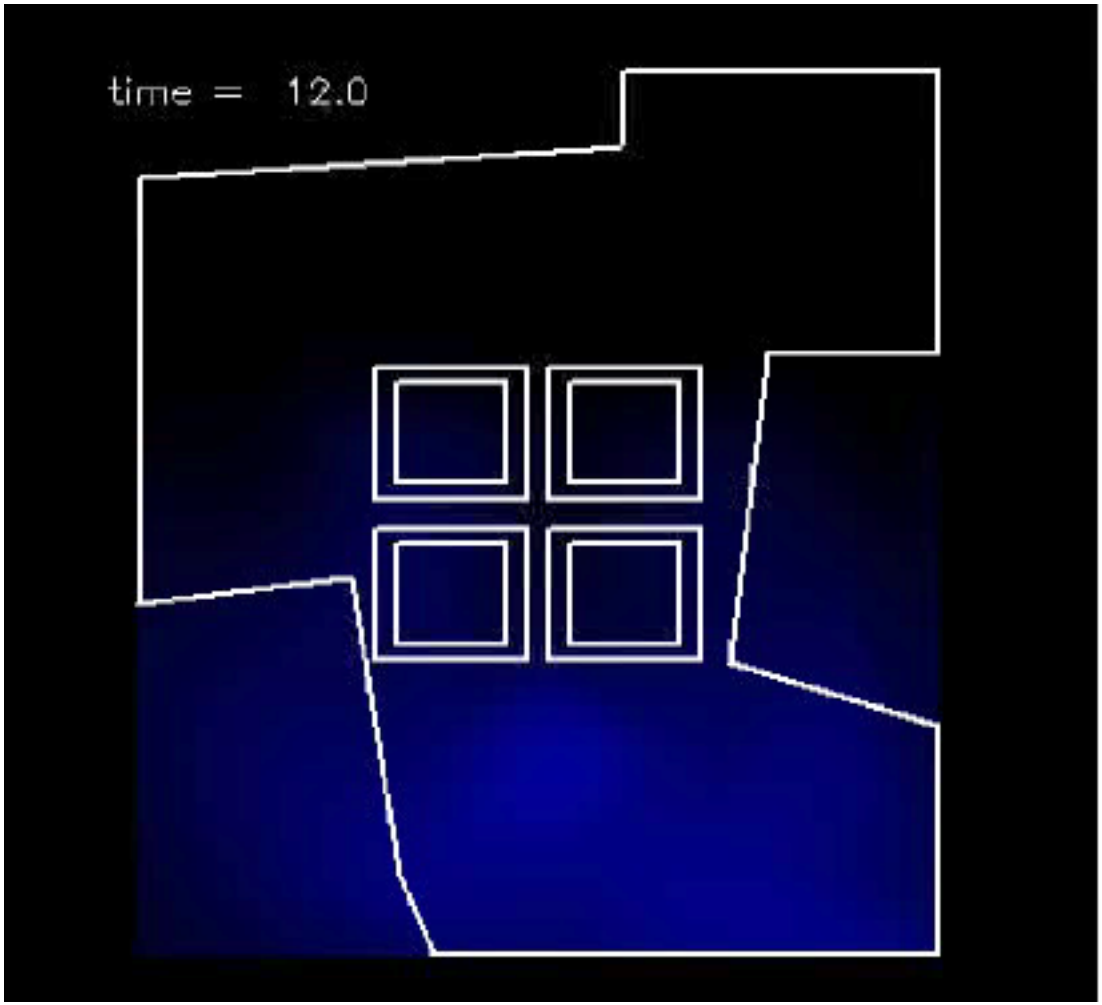


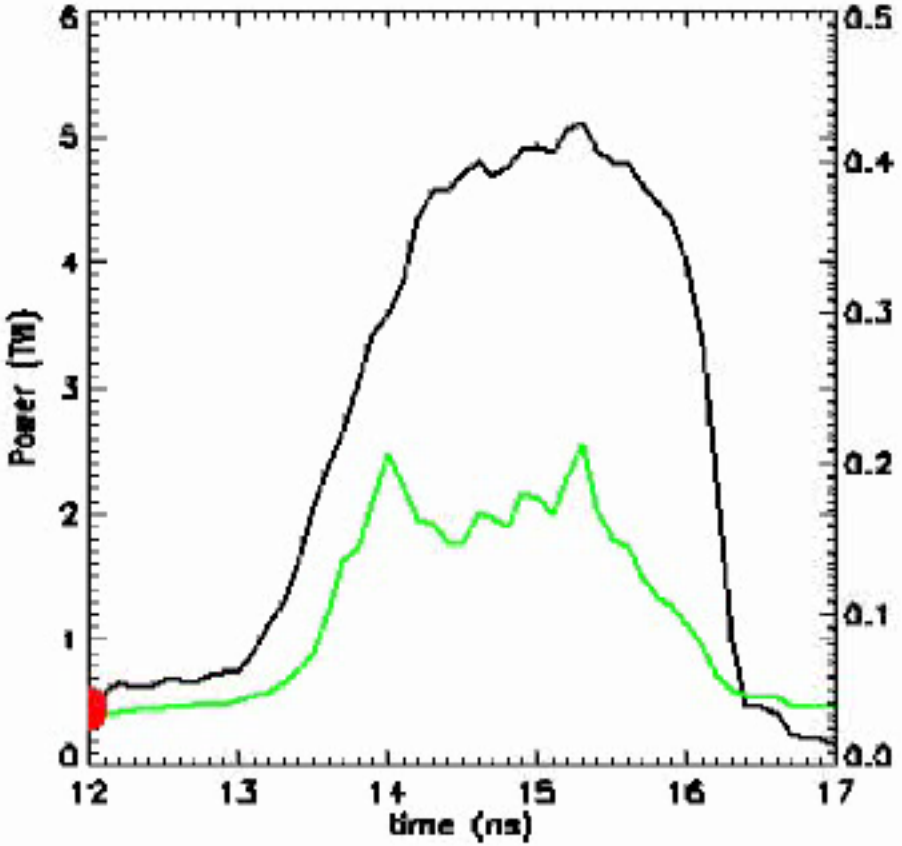


29 % SRS

Shot N0911107

NBI movie for a hohlraum with smaller capsule



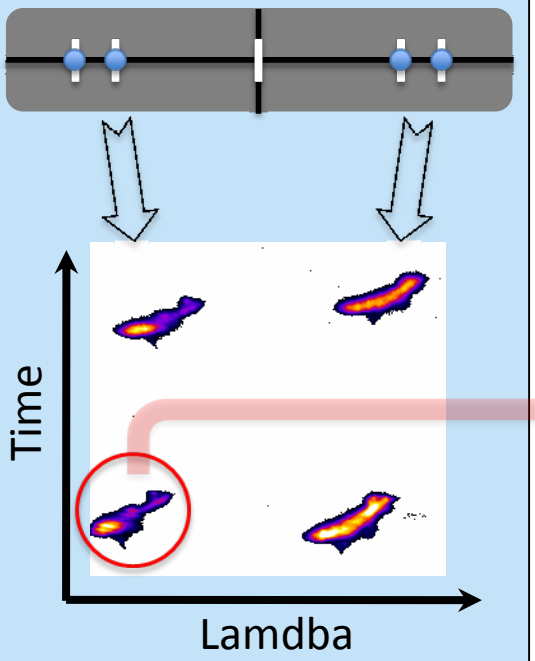


22 % SRS

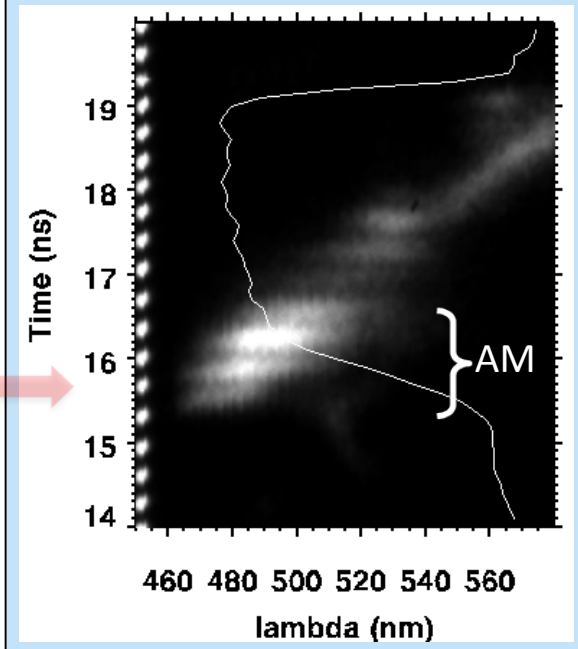
Shot N091114

The 4 beams are multiplexed in the spectrometer-streak camera

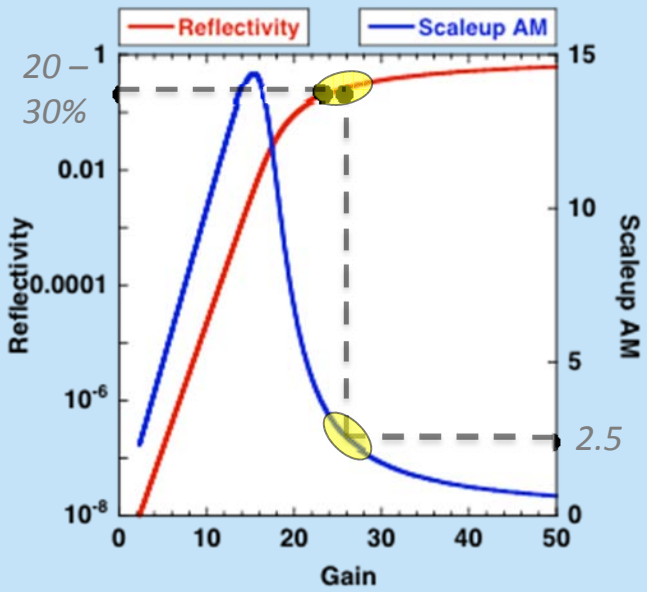
Spectrometer-streak camera input/output



SSD creates AM on the pump and SRS



Simple gain model shows SRS is partly saturated



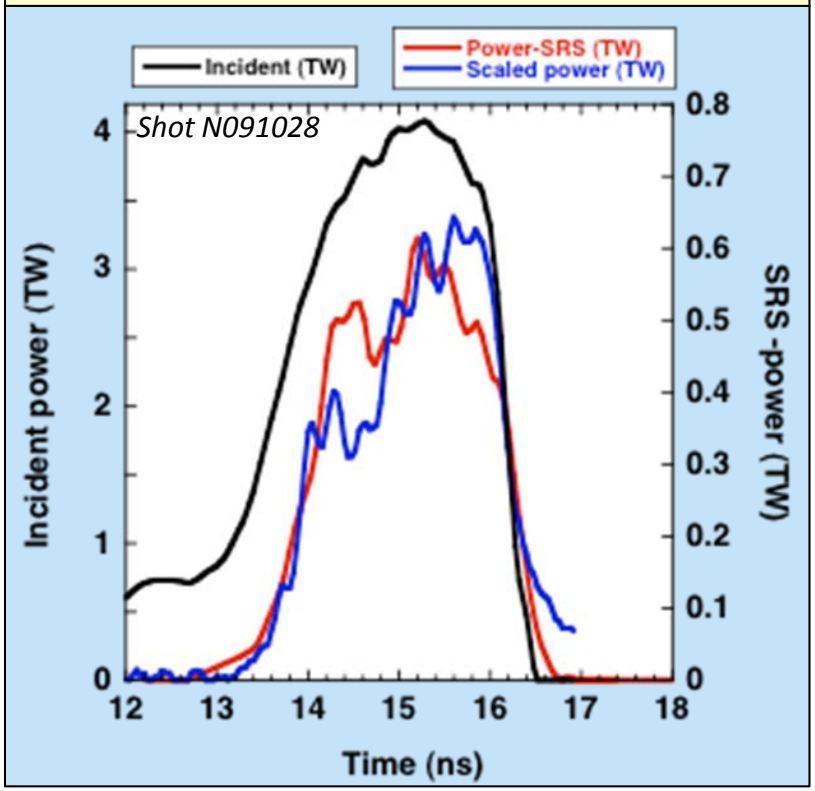
- The SRS is ~ 20% with AM ~ +/- 12%
- The pump AM is ~ +/- 4%
- A simple Tang growth model shows that these results are consistent with a *somewhat saturated* SRS

Summary

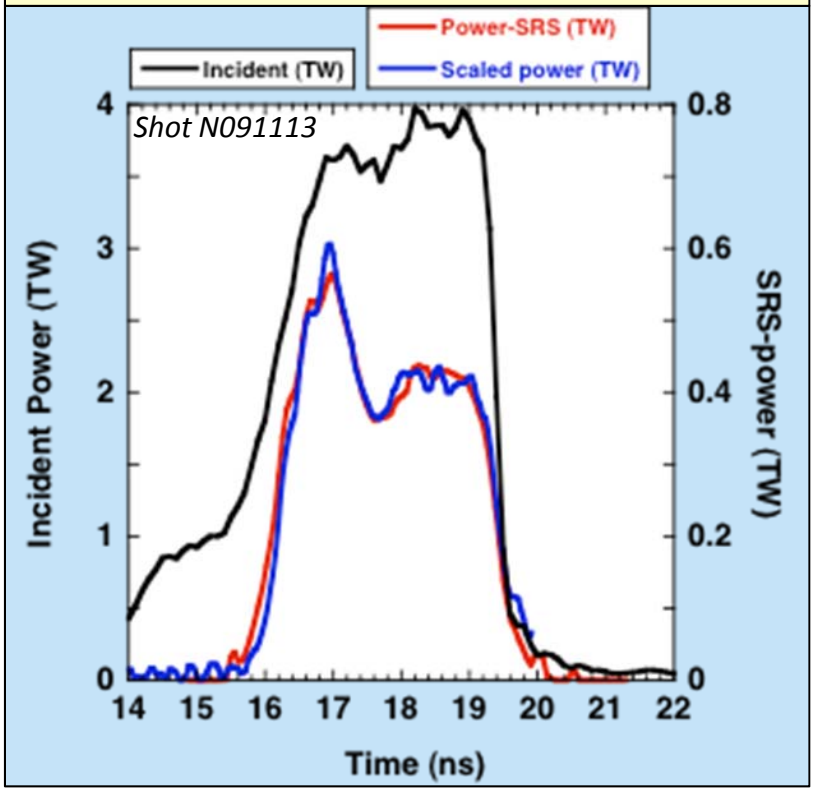
- Backscatter measurements have been activated on two quads in two beam cones on NIF
- The backscatter instrument consist of a FABS and NBI system which measure SRS and SBS separately
- Calibration techniques allow the instrument to achieve ~ 15% error on the power measurement
- A new time-resolved NBI shows that the time-dependence of the entire backscatter signal is well represented by the FABS fast diode
- The backscatter measurements have guided decisions relating to the laser operation and the target design
- Future efforts will expand the NBI plate operation to include a quad at 23.5° from the hohlraum axis

The NBI-TR shows a time-history that is similar to the FABS fast diode

720 kJ scale 0.9

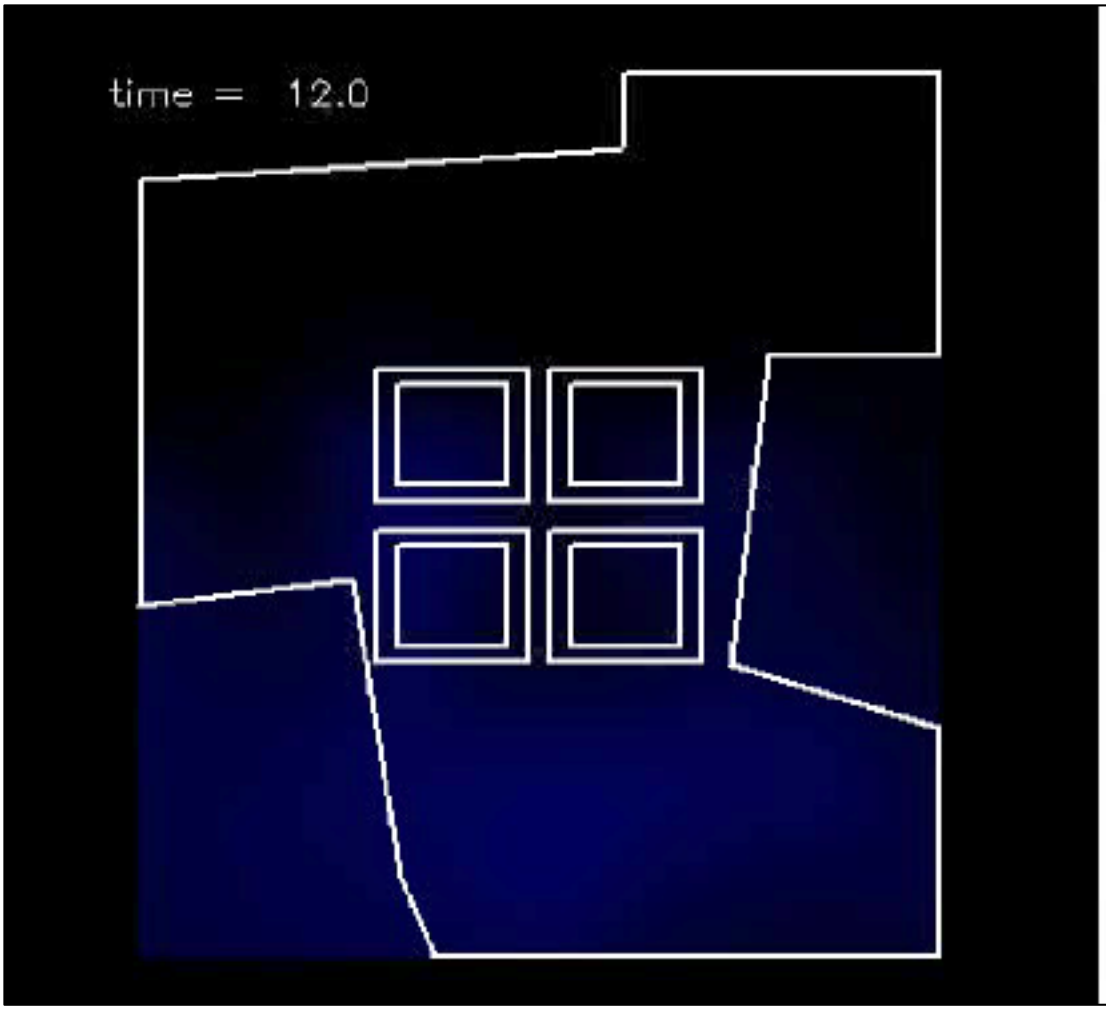


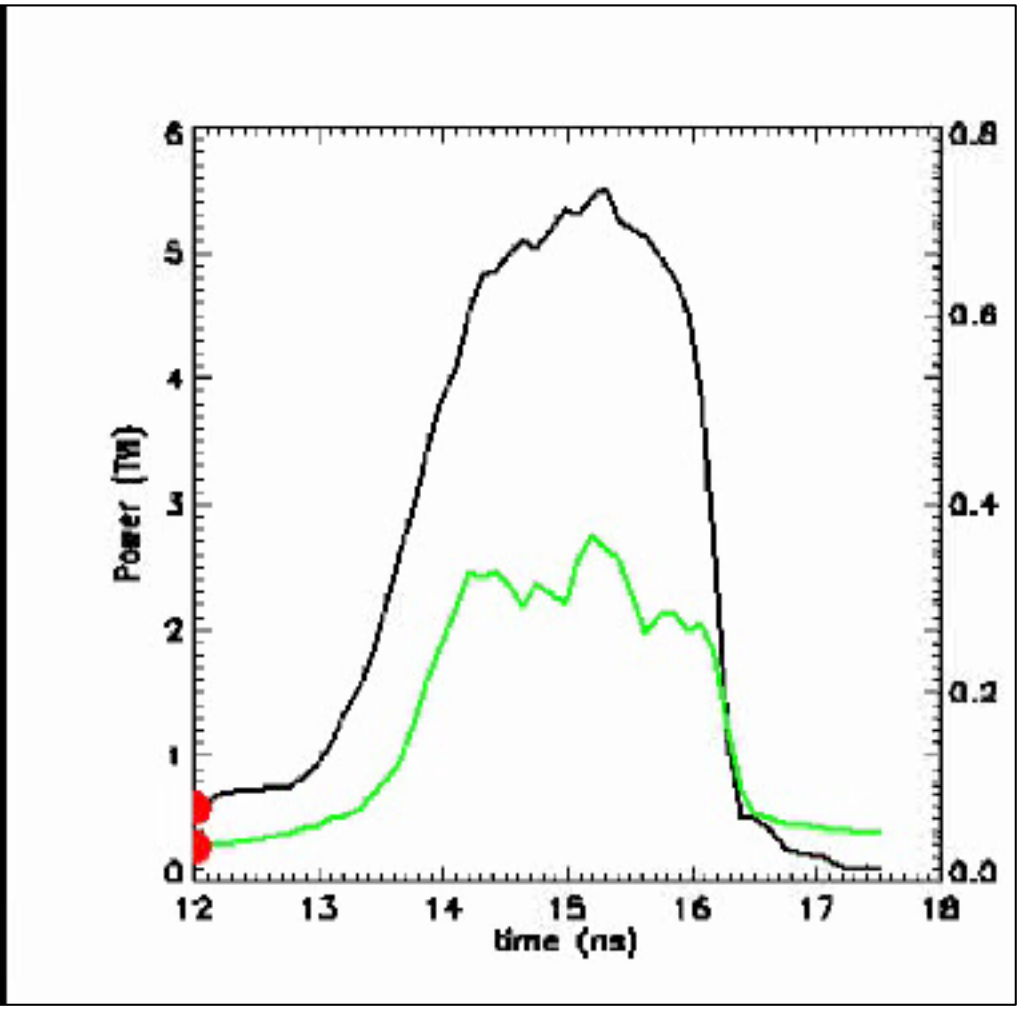
840 kJ scale 1.07



End

NBI movie showing significant AM

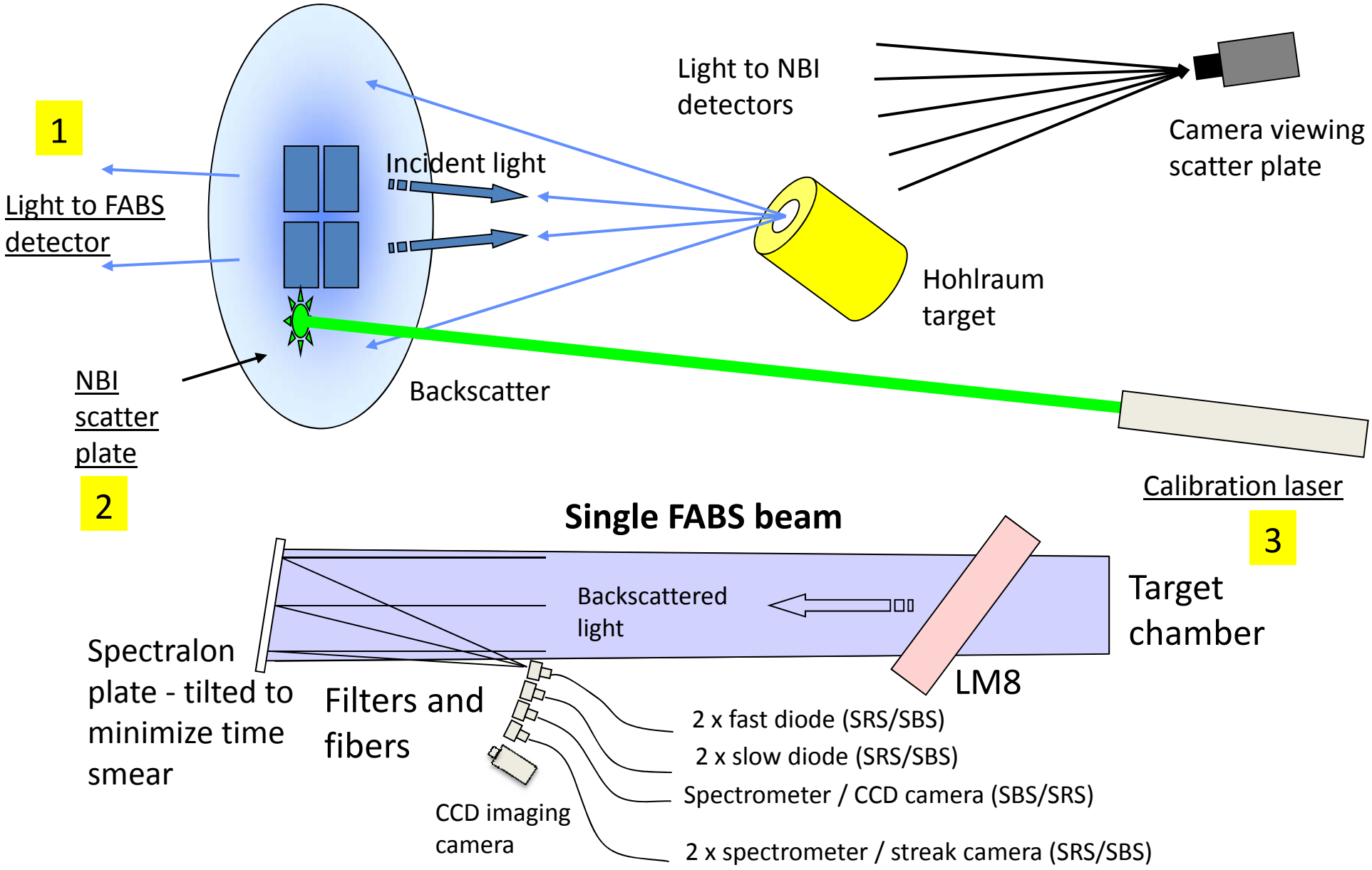




Shot N091025

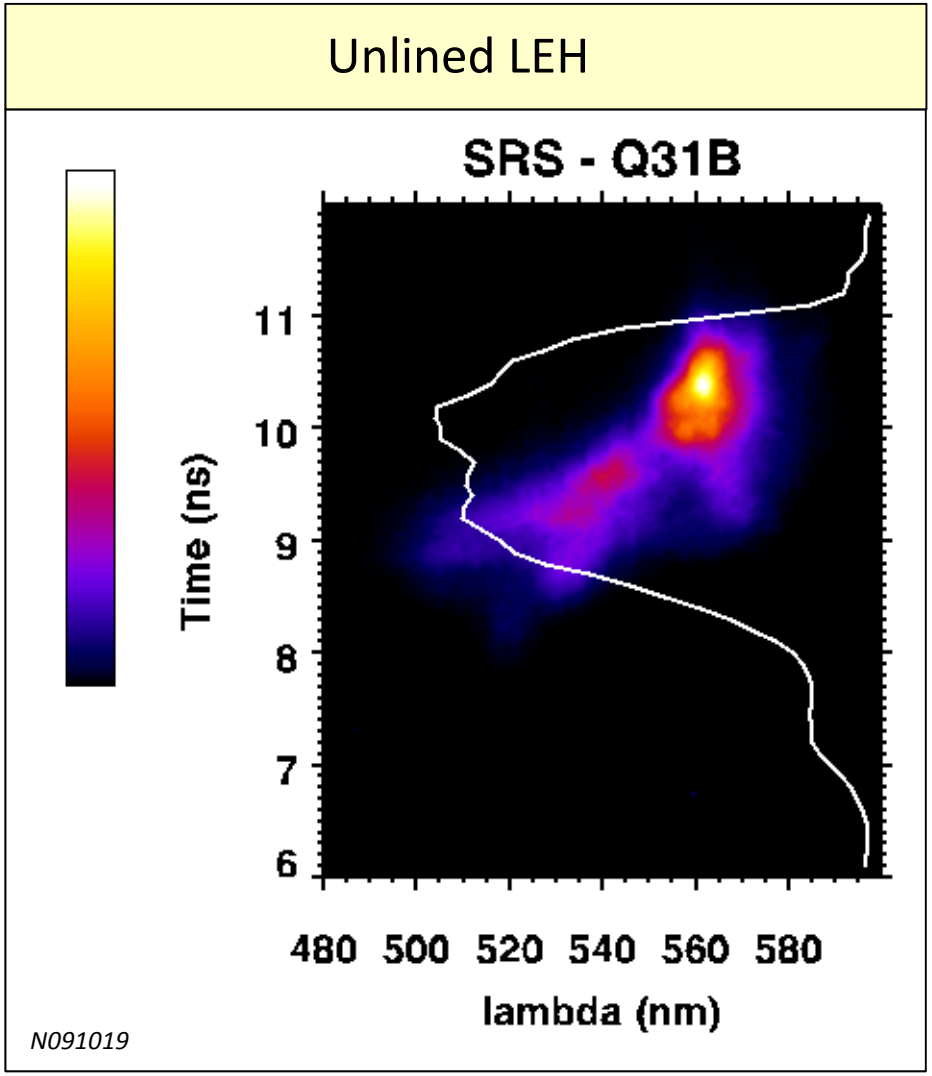
24 % SRS

The NIF system utilizes two instruments to measure backscatter light and one calibration instrument



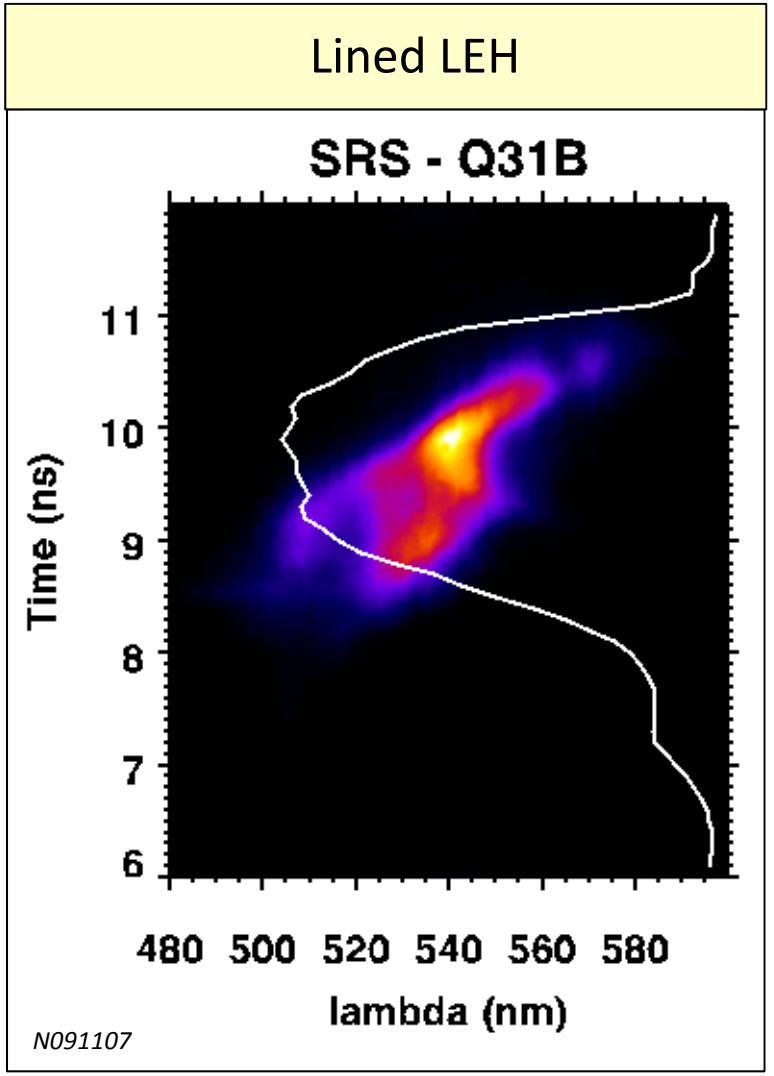
SRS spectra shows laser propagation to higher density/temperature from unlined hohlraum experiments

Unlined LEH



13 % SRS

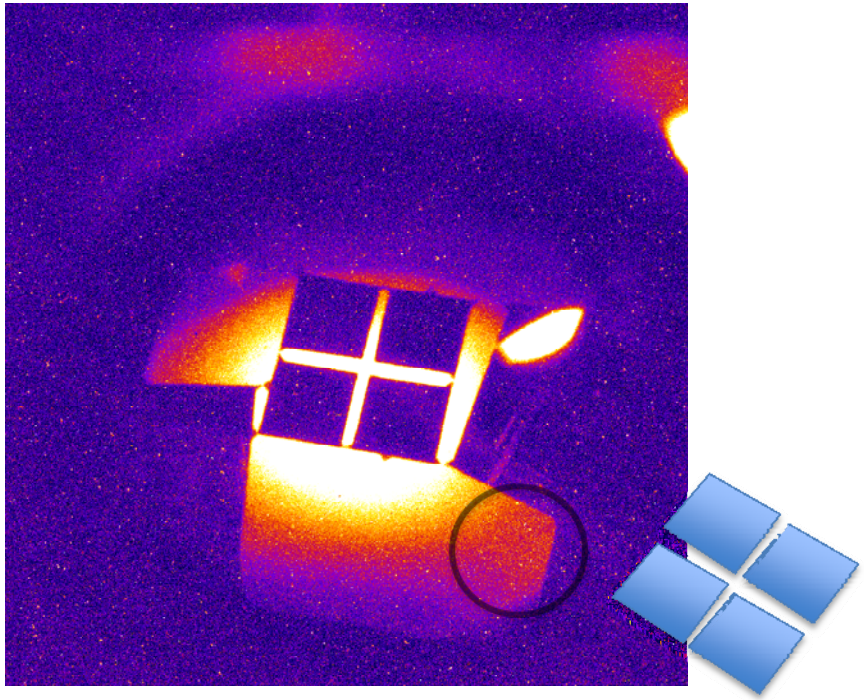
Lined LEH



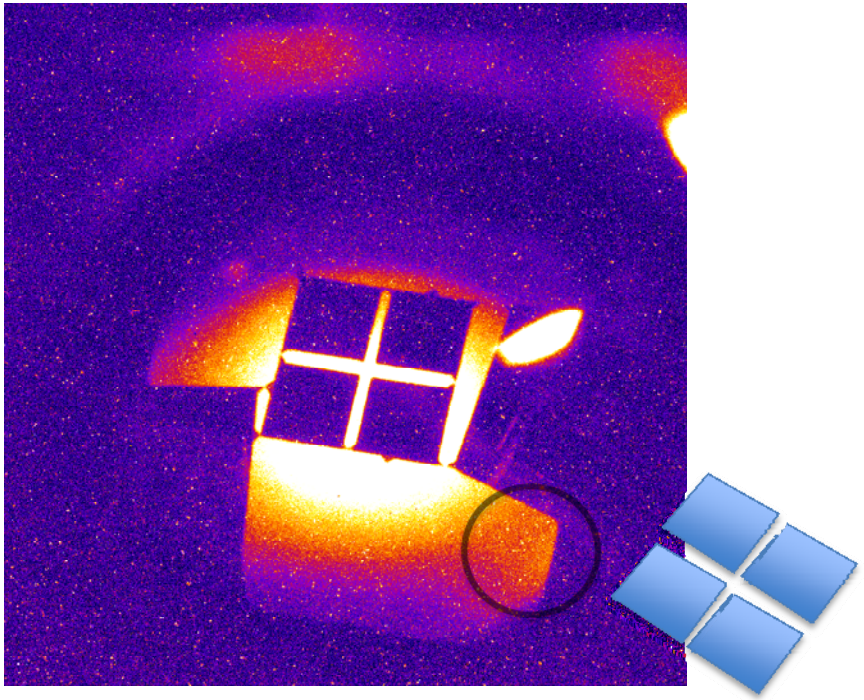
29 % SRS

Future plans: measure SRS on 23.5 cone quad

N091030 ($\Delta\lambda$=3 Å)



N091030 ($\Delta\lambda$=8.5 Å)

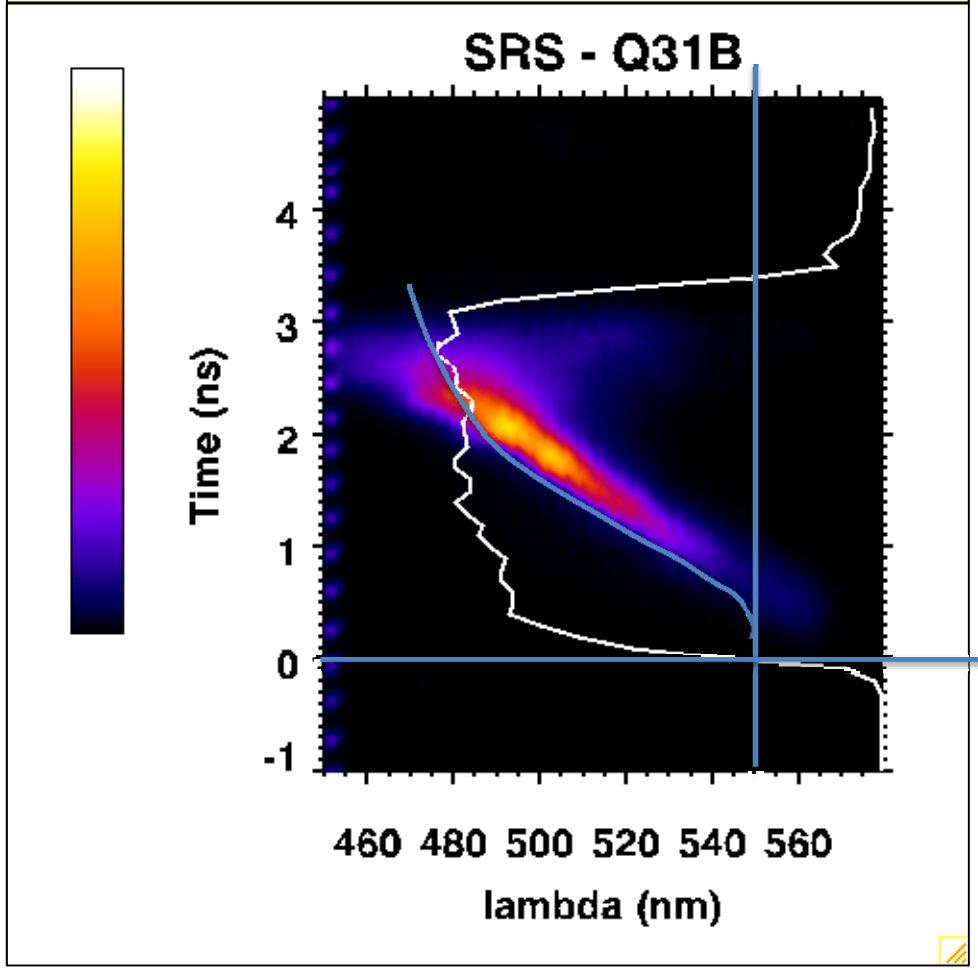


Approximate 23.5°
quad location

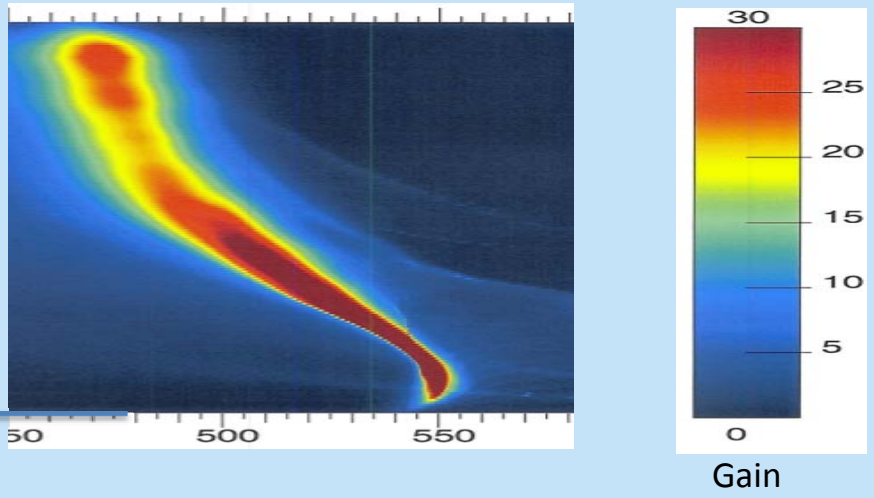
These shots and others show an increase in the light at the lower corner of the scatter plate

SRS spectra from a C5H12 gaspipe experiment is approximately reproduced in simulations

Stimulated Raman Scattering (SRS) spectral time-dependence data



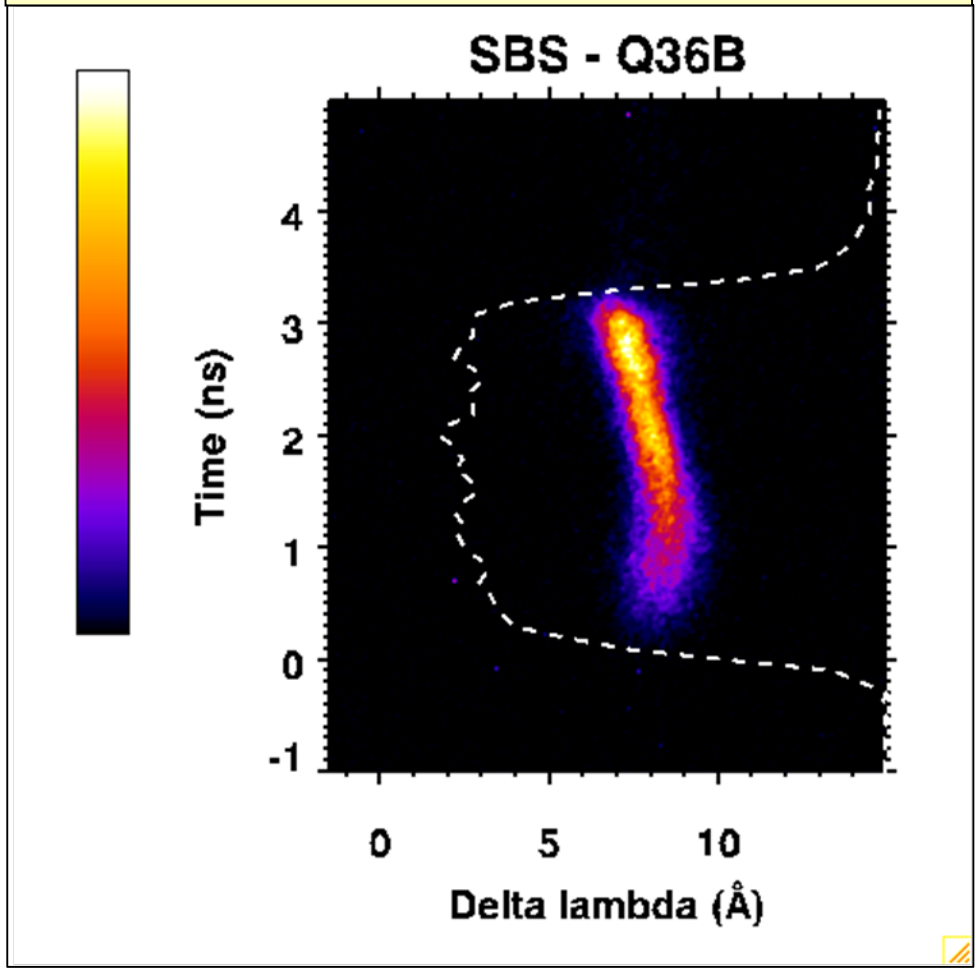
Stimulated Raman Scattering (SRS) spectral time-dependence simulation



18 % SRS

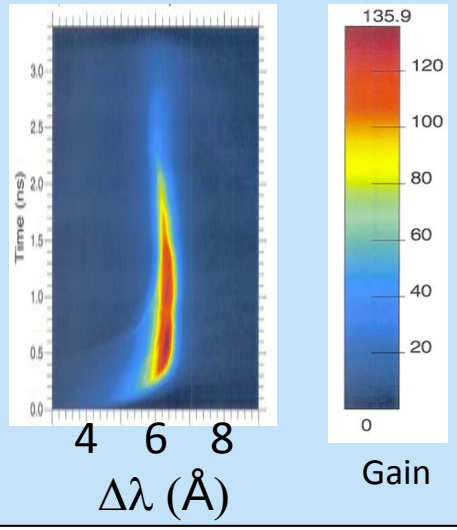
SBS spectra from a CO2 gaspipe experiment is approximately reproduced in simulations

SBS spectral time-dependent data



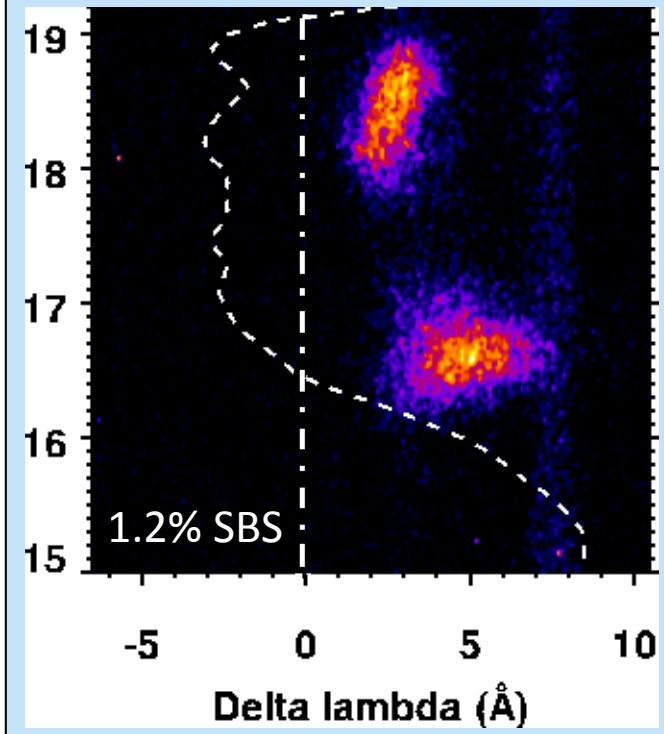
40 % SBS

SBS spectral time-dependent simulation

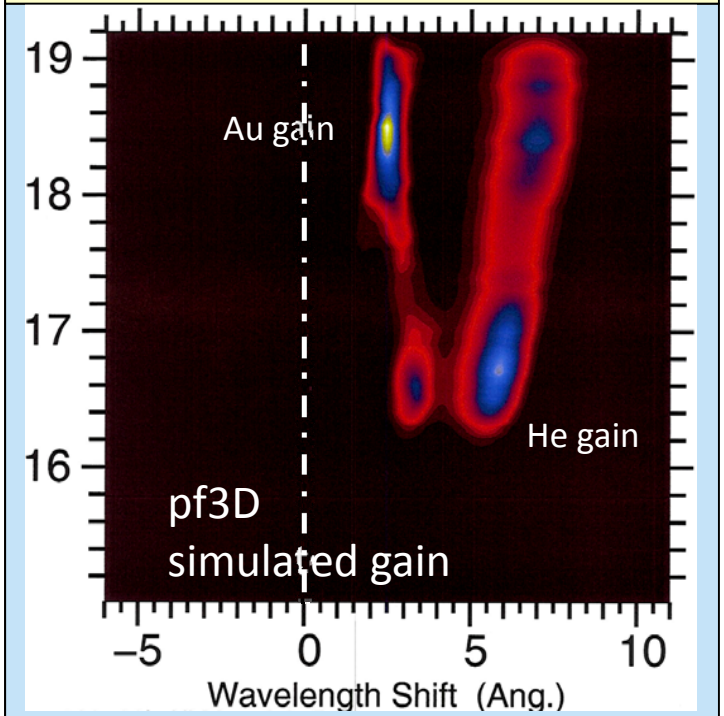


SBS outer beam spectra show good agreement with simulations

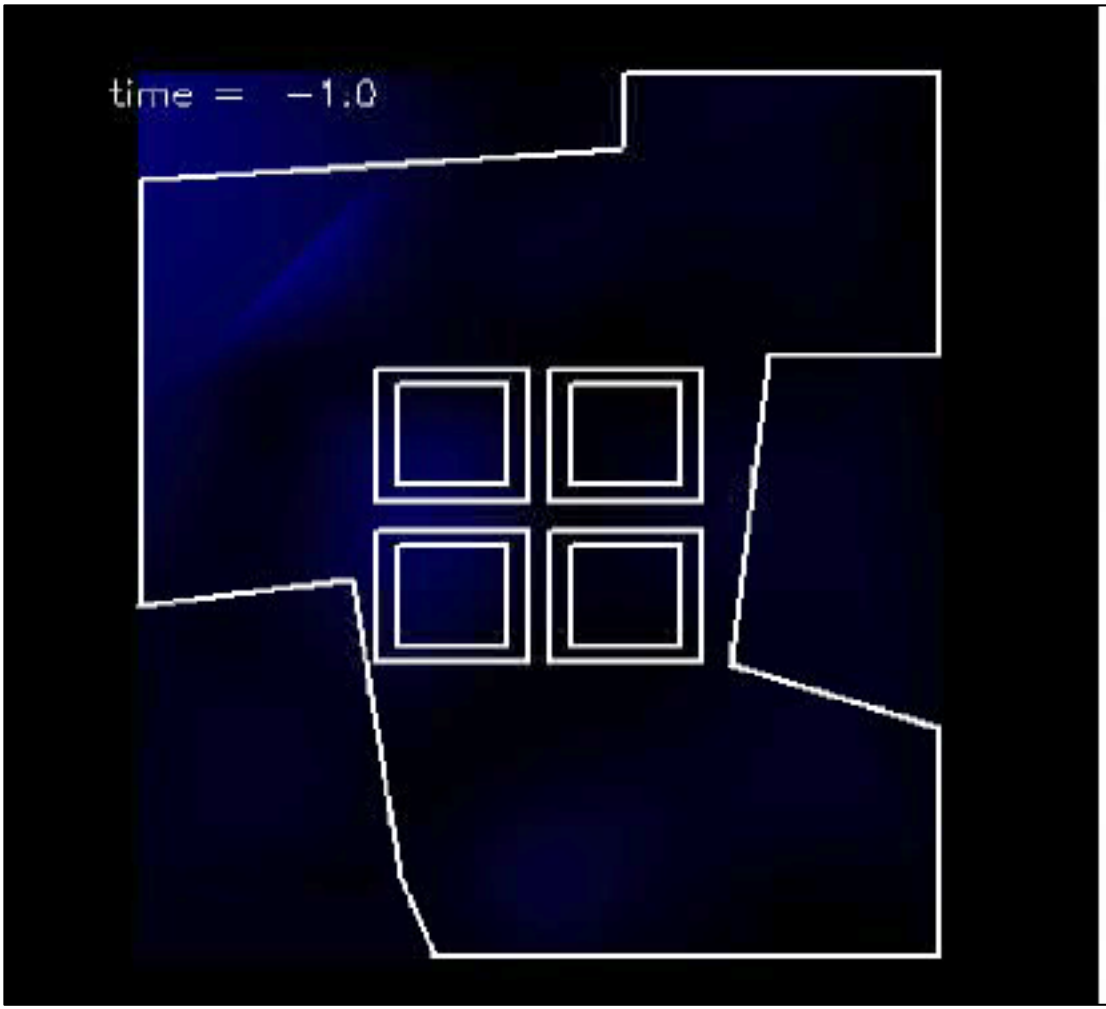
50° Quad SBS experiment

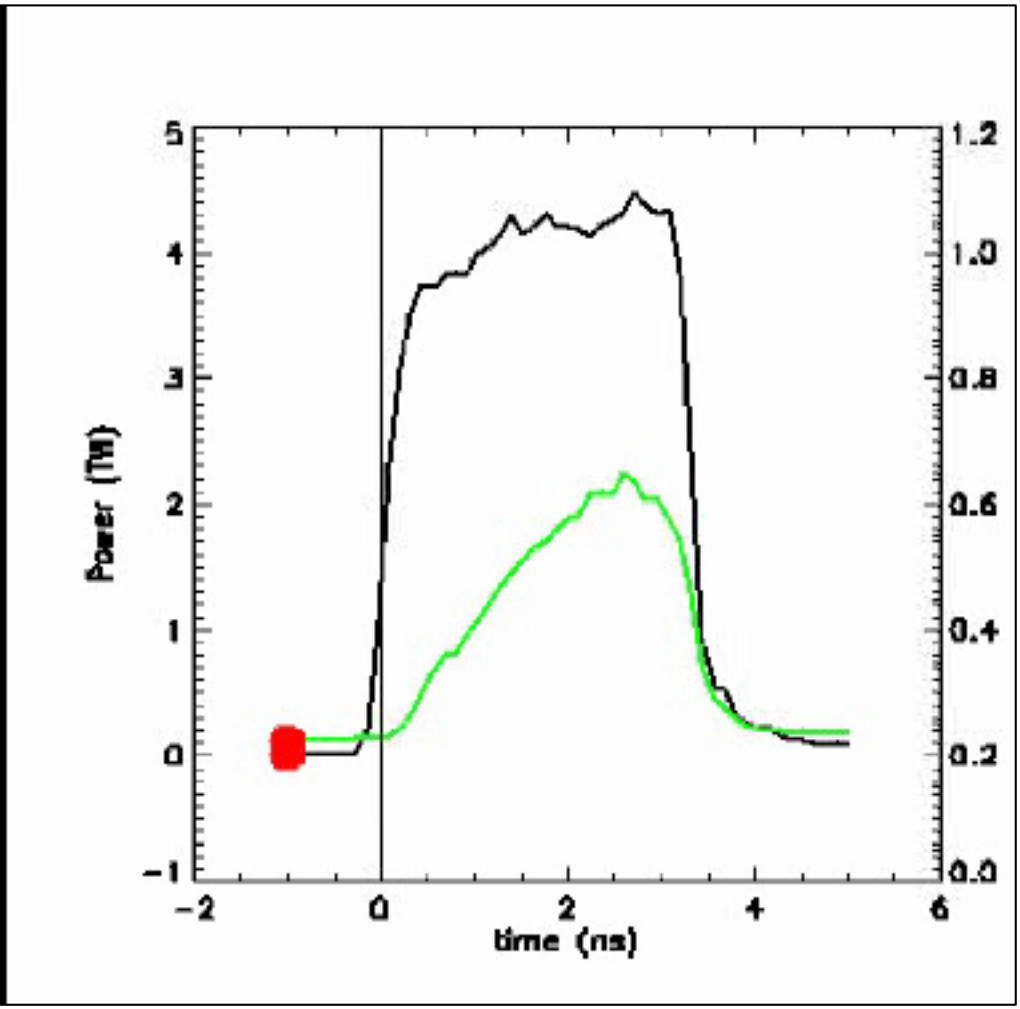


50° Quad SBS simulation



NBI movie for the gaspipe



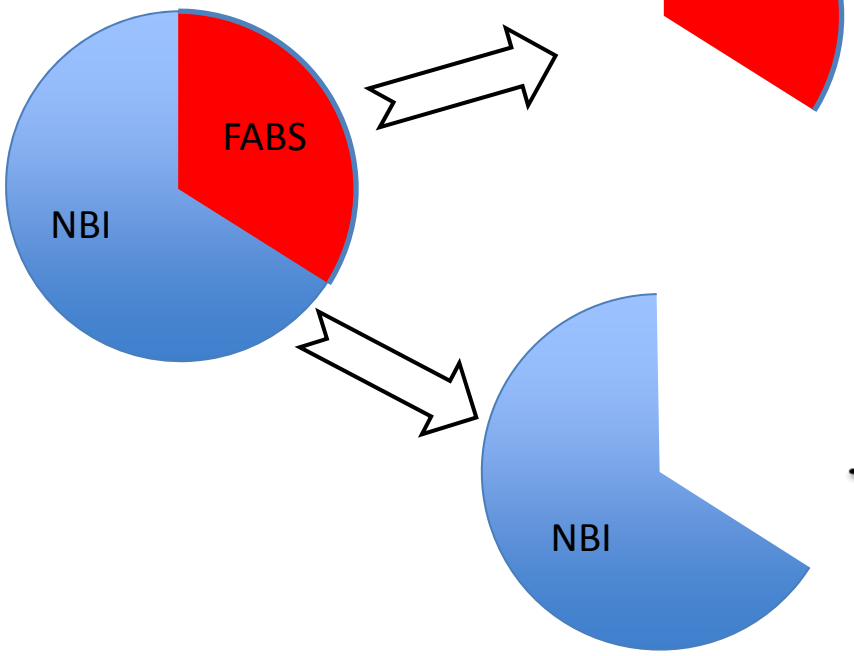


19 % SRS

Shot N091202

Error summary

Typical backscatter content



FABS	SBS	SRS
LM8	+/- 18%	+/- 14%
Instrument	+/- 8%	+/- 8%
Filters	+/- 4%	+/- 4%
Total	+/- 20%	+/- 17%

NBI	SBS/SRS
Cal	+/- 5%
Analysis	+/- 8%
Time-dep	+/- 10%
Filters	+/- 4%
Total	+/- 14%

Overall error = 20% * 1/3 + 14% * 2/3 = 16%